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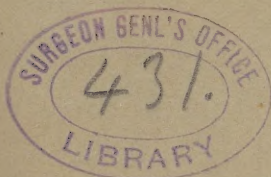
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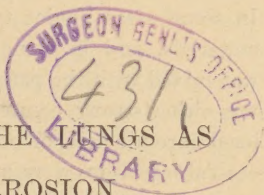
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A STUDY.
THE ANATOMY OF THE LUNGS AS
SHOWN BY CORROSION,
CONSIDERED IN RELATION TO PULMONARY PHTHISIS.*



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IN this paper I must apologize for repeating certain matters already published. This is necessary in order to make clear the facts and theories presented. The subject is sufficiently interesting, I think, to justify some repetition.

DURING the last year I showed, at meetings of the Practitioners' Society, and also of the Pathological Society, several specimens which illustrated more or less perfectly the anatomy of this little-explored region of the lung. I show you to-night specimens which I think will demonstrate with a good deal of completeness a number of details of considerable practical or theoretical interest. Some of these specimens have already been shown to the societies named, but many have not.

The method employed has been by injection and corro-

* Read before the Section in General Medicine of the New York Academy of Medicine, December 16, 1890.

sion. The details of it have been communicated to the Pathological Society during the past two years. It is not necessary, therefore, to go over them again, except in a very brief manner. The mass usually used for injecting was a mixture of paraffin, wax, and resin in varying proportions. In some cases Venice turpentine was added to the other materials, and in some neither this substance nor resin was mixed with the paraffin and wax. The corroding agent was either strong commercial hydrochloric acid or crystallized chromic acid, or both. In one or two cases fairly successful injections were made with white celluloid, dissolved in alcohol and ether, and mixed with variable amounts of gum-resins, collodion, linseed oil, and pigment.

As the object of the preparations was to indicate as nearly as possible the actual course of the various structures during life, before injecting the bronchi the lungs were always inflated, and were always supported as carefully as possible while the injection was made by paraffin poured over them, and by being floated in the melted paraffin.

The technique I have communicated, as I have said, to the Pathological Society. I must add that if any one wishes to adopt the method he must be prepared for many failures. Practice alone will give the ability to make good preparations. There is something also which can be shown, perhaps, but can not be described, which may determine success or failure. I shall be most happy to show practically how I make the preparations, and all I know about the method, to any one who will take the trouble to try it.

There seems to be something demoralizing about corrosion studies. In Europe, those most successful in them seem to have tried, even when professing to publish them, really to keep their methods secret by omitting to mention certain practical details. There is a tendency to do this

sort of thing among a certain class of European observers. In this country we do not, as a rule, apply the methods of trade to science, and make capital by keeping scientific processes secret for personal advantage. We may perhaps follow European methods too closely in many ways, but this particular fashion we do not often affect. There are a few American scientists, perhaps, whose view of science is so selfish that they fall into the contemptible way of attempting to aggrandize themselves, regardless of the loss of time to others and the duty of helping, for the general good, by every means, the advance of knowledge; but they are rare.

In corrosion specimens we are only concerned with the form of the things studied. We naturally have nothing to do with the tissues which bind the organs together or with the structure of the walls which contain the casts, since these are purposely destroyed by the acid.

The bronchi differ upon the left and right side. The left lung, having no middle lobe (or probably, as Aebys says, no upper lobe), has usually two main tubes—one for the upper and one for the lower lobe. The branch to the lower lobe is practically the same in both lungs. A line drawn through the center of this bronchus, beginning at the entrance of the primary bronchus and terminating at its first branch, may be regarded as the central stem of the lung. All the bronchial tubes radiate from this center. I think it may also be said that this line is the center of the expansion of the lung. From it all the bronchi and the arteries run normal to the planes of expansion. The right bronchus differs from the left, because of the large branch given off to the upper lobe and the subsequent distribution to the middle and lower lobes. I show some specimens of partially injected lungs which demonstrate the course of the larger tubes.

There has been some dispute as to the mode of division of the bronchi. Certain observers have stated that they invariably divide into two. Others, following Aeby, say that the division is always axial. The specimens of adult lungs which I show you demonstrate, I think, the extent to which each of these sets of observers is correct. An uneven dichotomy, as Ewart calls it, may perhaps describe the mode of division, but "uneven dichotomy" is rather a vague term. In the child's lung there is evidently one large descending bronchus, running through the posterior inner part of the lower lobe, carrying air to it, and from this a number of smaller tubes are given off. The other lobes also show a rather similar arrangement. In the adult lung these main tubes are more difficult to show, because of the great relative increase in size of their various original branches. Good casts even of the child's lung, moreover, show several smaller tubes besides the larger one arising from the main bronchus.

It is rather interesting to note that injections made in the way in which Professor Aeby made them, with fusible metal and with very low pressure, are exceedingly apt to give a mold which resembles almost exactly his well-known diagram. Injections made, however, with the same metal under high pressure, as was done by Ewart, give a different picture. And the same may be said of injections made in the way which I myself have adopted. The specimens figured by Ewart, as well as those which I now show you from adult lungs, are very hard to reconcile with Aeby's description or diagram. The various tubes starting from the center mentioned run toward the surface of the lung in as direct a manner as is possible, seemingly normal to the planes of expansion of the organ. They give off branches one at a time, but they can not be said strictly to divide either axially or dichotomously. The arteries follow the

course of the bronchi. Each branch of artery and each branch of bronchus correspond exactly. The veins pursue an absolutely different course, and, as has already been pointed out by Ewart, run as far as possible from the arteries and bronchi. In a paper published last year I called attention to the fact not only that the veins ran, as Ewart in his book has pointed out, as far as possible from these other structures, but also that their general course was such as to make them cross the bronchi and arteries again and again before they reached the surface of the lung. This course can not be demonstrated positively to be such as to bring the veins always in nodal places in respect to lung expansion, but it seems very probable that the air-pressure in the bronchi is so balanced by elastic retractile force that the latter actually, during both inspiration and expiration, tends to hold the veins open. In this way the obstruction to the blood current through the veins is reduced to a minimum. During inspiration, the arteries, like the bronchi, are pulled upon longitudinally, and the chest expansion which draws air into the bronchi also tends to draw blood into the arteries. During expiration, while air is expelled, the arterial blood-pressure is also raised as the contraction of the chest tends to force blood back toward the heart. As far as the veins are concerned, it seems very probable that neither the expansion nor the contraction makes much difference in their blood-pressure. It will be noted that the veins of the body correspond to the arteries of the lung, and that the veins of the lung correspond to the arteries of the body, and it seems likely that, as the systemic veins feel so greatly the respiratory movements, so also do the pulmonary arteries. The pulmonary veins may almost be regarded as being outside of the chest, so far as the physical effects on their blood-pressure produced by chest motion are concerned, and even to a less degree than the systemic arteries should be affected by such motion.

The pulmonary arteries have a peculiarity which is not unlike that of the portal vein in the liver; they give off a very large number of small side branches. An arterial trunk, for example, a quarter of an inch in diameter, may be shown to give off thousands of little trunks, so that in some preparations it looks as though it were surrounded by

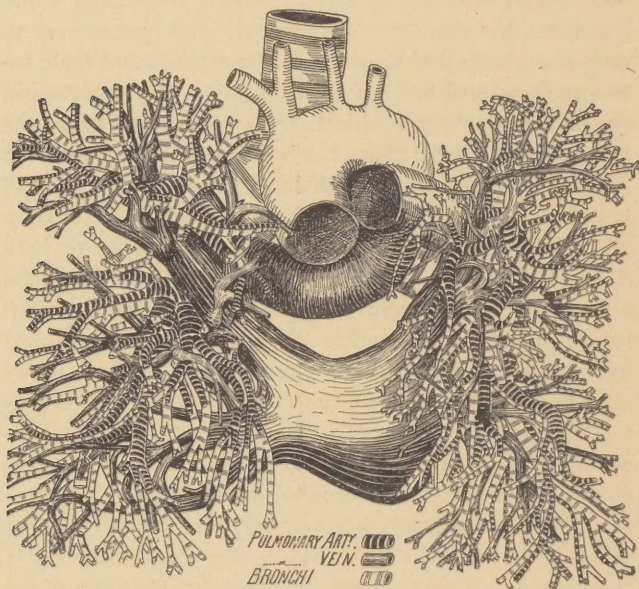


FIG. 1.—A DIAGRAM OF THE PULMONARY ARTERIES AND VEINS AND OF THE BRONCHI. (After Ewart [bronchi and pulmonary vessels]; reproduced with the kind permission of Dr. Ewart.) The course of the arteries accompanying the bronchi is shown, while the veins are seen to pursue a different course.

fine moss. The pulmonary arteries are, of course, all to be regarded as terminal vessels. There is no communication between any large trunks. This is not at all the case with the veins, whose branches (at least on the surface of the

lung) communicate very freely with one another. One vein, moreover, receives blood from a number of surrounding arteries.

The bronchial arteries, and the question whether they empty into the pulmonary artery or vein, have been the subject of much study. There is, of course, no doubt that a considerable portion of the blood nourishing the larger bronchi is returned to the systemic venous system through the bronchial veins. What becomes of that which nourishes the smaller tubes and, I must add, the walls of the pulmonary arteries and veins, is the question. The greater number of observers maintain that this blood is poured into the pulmonary veins, and not infrequently it is said thus to "contaminate" the systemic arterial by mixing some venous blood with it. Certain observers say that this amount is so small as to be of little moment. Others think it likely that the closeness of the air to the capillaries of the fine bronchi renders this blood arterial at once, and that, therefore, there is no such "contamination."

That this question should ever have been a matter of dispute seems to me to show that there was no reason for the dispute. Evidently the bronchial capillaries empty somewhere, and equally evidently after reaching tubes of a certain size they do not unite to form bronchial veins, but empty into the pulmonary vessels. Now, there is a physical matter connected with this question usually overlooked. It is this: The bronchial arteries must necessarily empty after forming capillaries into the vessels whose pressure is less than that of the blood which has overcome the resistance of these capillaries. If the pressure in the pulmonary artery exceeded that in the capillary plexus of the bronchi, the current would flow toward the bronchial arteries until the forces of the left and right heart counterbalanced one another, when stasis would result. The pulmonary arterial

pressure can hardly be less than that of the bronchial capillaries, as it is produced by the strong right ventricle. It is evident, moreover, that the pressure in the pulmonary veins is less than that in the pulmonary arteries, and it is stated to be less than that of the systemic veins. There can be theoretically no question that the bronchial vessels must empty into the vessels having the least pressure—*i. e.*, the pulmonary veins.

I have said that these vessels empty into the pulmonary veins because in them there is the lowest blood-pressure. The fact that the pressure in the larger pulmonary veins is less than that in the vena cava does not necessarily prove that the blood which passes the bronchial capillaries is lower than that in the pulmonary arteries; but if it is not so, then pressure of this blood must be greater than that in the pulmonary arterioles, in spite of the force of the right ventricle. I can not say that I have demonstrated the course of these vessels, but I can say this much: After injecting the pulmonary blood-vessels and tubes with a paraffin mass, I have injected the bronchial arteries with a mixture of collodion and celluloid and other substances soluble in ether and alcohol. The injections have never been sufficiently perfect to enable me to say positively that the blood from them entered the pulmonary veins. In one or two of them, however, it seemed that this artery broke up into capillaries through which the mass had passed and from which it had apparently run directly to the pulmonary veins. From microscopical study of the lungs injected with gelatin and Prussian blue in the usual way, through the pulmonary artery and vein, in which lungs, however, the injection had been sufficiently complete to fill the bronchial arteries and run out through their main stems, it seems demonstrable that the bronchial arteries form a capillary net-work in the walls of the smaller bronchi, and that the

capillaries traverse the peribronchial connective tissue and directly communicate with the capillaries of the air vesicles which are nearest to the bronchi. It seems, therefore, almost certain that the bronchial arteries simply break up, as all arteries do, into capillaries and nourish the tissues through which they run, in doing which their blood gives up oxygen and absorbs carbonic acid. The capillaries of these arteries, however, after reaching the smaller tubes, communicate with the pulmonary veins indirectly through a set of capillaries which are a part of the respiratory system of the lung itself, and in these they immediately give up their carbonic acid and take oxygen from the air. Through these capillaries we have a direct connection between the pulmonary and systemic systems of vessels; but the blood passing through them can not be said to contaminate in any way the blood in the pulmonary veins. I show a specimen in which a more or less complete injection is made of the bronchi and bronchial vessels and of both sets of pulmonary vessels. It is rather interesting to note that this specimen shows the branches of the bronchial arteries passing through and running upon the surface of the pulmonary arteries as well as upon the surface of the tubes.

After the careful and satisfactory work done by Ewart it is not necessary for any one to attempt to describe and name the branches of the bronchial tubes or of the blood-vessels. It is advisable, however, to call attention to some points, since the recent work of Koch and his well-known treatment for tuberculosis may give an extreme amount of importance to the surgery of the lungs.

Now, these organs can not, from a surgical standpoint, be studied after the usual style of the scientific anatomist, for there are practically no landmarks within them to guide the surgeon. It is as well, therefore, to call the attention to a few facts which the specimens that I now show dem-

onstrate plainly. Owing to the course of the arteries and bronchi from the root toward the surface, a course practically always normal to the planes of expansion, an incision made parallel to any part of the surface will cut a great number of air tubes and arteries. An incision made from any point on the surface toward the central stem will avoid most of these structures. In an operation, therefore, upon the lungs this fact is to be borne in mind, and, whatever method is devised, it will be found that the incisions made in the lines radiating as has been described will necessarily do the least damage and produce the least hæmorrhage. The same statement is true in regard to collapsed lungs; but in this case the course of the vessels and bronchi is by no means so straight as it is in the expanded organs. The artery running to any part of the surface may be compressed by pressure at a point over any line drawn from it to the root. Ewart demonstrated collapsed lungs. The specimens shown to you were all expanded fully before the injections were made, and therefore represent much more nearly the actual condition of things within the chest when the lung is not collapsed.

In this connection it is not perhaps worth while to direct attention to the fact that in all probability it would be perfectly easy to operate upon the lungs without allowing them to collapse. Probably the whole lung would remain expanded if the patient breathed compressed air. It would be very easy to devise and apply an apparatus which would increase the pressure within the chest, and through this ether might be given. It would only be necessary to have a mask so shaped that it would fit closely over the nose and mouth. The ether could be given through this mask and suitable valves would permit of inspiration and expiration taking place. It is very likely that with such apparatus a large portion of the lung

might be laid bare and freely incised without causing the least collapse of it. Of course it will be understood that this is merely a suggestion possibly of no earthly value. But it is a suggestion sufficiently plausible to be worth thinking about.

The anatomy of the finest bronchi, and of the lobules, is shown in a number of casts presented to-night. Two drawings, made by Dr. H. Macdonald, from sketches of my own, illustrate the appearance of the air-passages and air-vesicles under a moderate power. The reproductions of these and a description of them will appear in the *Pathological Society's Proceedings*.

The sudden breaking up of the pulmonary artery into capillaries, which is well known to occur at its entrance into the lobules, is of peculiar interest, because it takes place where the bronchi subdivide into air-passages, and because also it is at this place, according to Rindfleisch, that the miliary tubercles have their original site. This author believes that the reason that these tubercles are found most frequently in the situation mentioned is to be explained by some peculiar behavior of the air currents. It is not necessary to go over his views. It is, however, worth while once more to call attention to this fact: that, in spite of experiments showing the possibility of infection by dried tubercle bacilli kept floating in the air, there is yet no proof that these actually enter the air-vesicles by inhalation and not otherwise. The question has not yet been answered in a satisfactory way why tubercle bacilli are inhaled into the upper lobes of the lungs in so many cases, while the bacteria of pneumonia in a vast majority of cases are lodged in the lower lobes; moreover, it still remains to be explained why in so very many cases the tubercles are found on the surface of the lungs beneath pleural adhesions. There must be something very peculiar about air currents which so sharply

separate one bacterium from another, and which, moreover, seem to carry the tubercle bacillus with such tender care to the extreme surface, and there to lay it down in a pleasant though remote spot, where it may rear its family in peace and cause pleural adhesions.

The theory of inhalation seems to me absolutely improbable. Turning now to other ways by which the bacillus may be introduced into the lungs, we have only the lymphatic and the arteries. In regard to the former, I have been unable to find any proof that, under all circumstances, the lymph flows in the same direction. It is most probable, however, that it flows toward the root of the lung.

When we look at the course of the blood-vessels, we see that the pulmonary artery arises from the right ventricle and that it divides into two large trunks, both of which form arches with the radii of their curves toward the heart, and that the first branches from these are given off from the peripheries of these curves and then run almost straight toward the surface of the lung. Let us suppose that there is introduced into the right ventricle a small embolus of higher specific gravity than that of the blood plasma. Such an embolus would be expected first to be thrown against the upper wall of the main artery and then to enter one of the branches which supply the apex of the lung. This theory is founded upon the usual behavior of solid particles in moving fluids. Such bodies, if heavier than the fluid, are thrown against the peripheral wall of the tube which is curved. If the masses containing bacilli are very small they would, theoretically, reach the part of the apical artery near the pleural surface, and if somewhat larger, one would expect them to enter some of the branches of the artery and to be arrested exactly at the place where Rindfleisch says that the tubercles most often originate—namely, at the point where bronchus and

vessel enter the lobule and where the rather large artery suddenly breaks up into capillaries. The reasons which make this theory seem plausible need, perhaps, a little more explanation. In rapidly moving liquids which are inclosed in curved tubes it will be seen that the so-called "centrifugal force" would make particles heavier than the liquid tend to fly toward the peripheral wall of the tubes, and particles lighter than the liquid should tend to follow the wall nearest the center. Of course this is most marked when the tubes are large enough for the attraction of their walls for the contained fluid and particles to be of little importance, and when the solid particles are large enough to develop a momentum sufficient to overcome the friction of the fluid which tends to obstruct their motion. If the particles were very small, they would be apt to change their position but little in a fluid like blood in tubes of the curve of the pulmonary arteries when propelled at the speed of the blood current.

Looking at the arteries of the lung, as shown in these casts, it will be seen that the direction of the main trunk is such as to produce a sharp curve downward. The largest branch also runs downward to the lower lobe or lobes. When, however, the middle-sized and smaller branches are studied they are found to run quite straight toward the pleuræ, giving off still smaller vessels, nearly at right angles to the main trunk. This trunk, however, is pretty large until, near the pleural surface, it suddenly divides into a number of small vessels, and these reach, as is visible to the naked eye, almost to the surface of the organ before dividing into capillaries.

The behavior of small emboli heavier than the plasma would probably be different from that of large ones. They would be likely to take a course which would carry them lower down than larger ones, and also upon entering the

straighter vessels they would be more apt to follow the larger branches directly toward the pleura, and there to be arrested at the capillaries. If the emboli were numerous they would probably scatter more or less widely through the lung, as is the case in miliary tuberculosis. Although

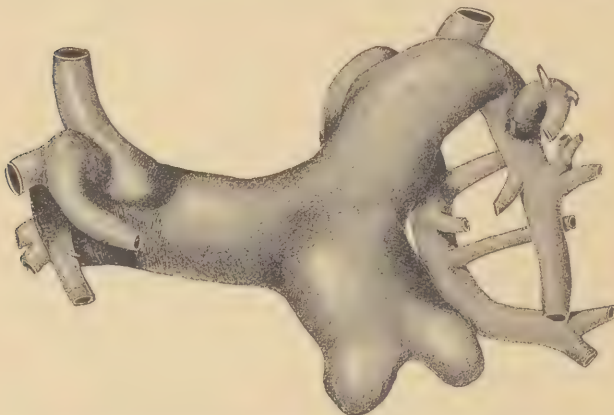


FIG. 2.—FRONT VIEW OF THE PULMONARY ARTERY AND SOME OF ITS PRINCIPAL BRANCHES. (From a metallic cast made by the author.) The pulmonary semilunar valves have made the two projections in the lower part. A representation of the fine details of the specimen is impossible in the present paper.

these very small bodies would, theoretically, be less affected by the curved course of the vessels than the larger ones, still they ought to feel its influence more or less, and tend, on the whole, to affect the upper rather than the lower lobes first. Of course the impediment to the circulation becomes greater and greater as vessel after vessel is plugged. Hence the blood current becomes slower and slower in the affected lobes as the process spreads. The current in the lower lobes then becomes relatively more rapid, and new emboli will be likely to be lodged at lower levels. It is also quite probable that the bacilli, having once caused the

tissue to break down, would then be distributed by the air currents, as well as in other ways. In phthisis the lesions usually begin in the upper lobes, and in many cases, besides the tubercular process and the pneumonia going with it, there is disease of the arteries, and the bronchial glands or some other lymphatics are tubercular.

In a previous paper I spoke of various objections to the inhalation theory of infection, and also called attention to the probability that all parts of the lung were expanded, in proportion to their bulk, by the chest movements. Unquestionably the region of least actual motion must be in the vesicles about the root and those lying near to the spinal column, but it is most probable that the chest movements are such as to affect equally every lobule throughout the lungs.

Those who would explain the frequency of tubercular disease of the upper lobes by infective matter carried by the air currents give various ways in which they think it takes place. Some contend that the upper lobes move less than the lower, owing to the form of the ribs. Why this should cause them to inspire bacilli oftener than the lower lobes is not clear, but we are told that it is not because the bacilli are drawn in, but because they are not forced out. The expiratory power is insufficient, and during coughing, etc., the air is forced into the apices, carrying with it secretions containing infective matter. If this statement is correct, why do we not frequently find the upper lobes choked up with these secretions?

Any theory based upon the thoracic respiratory movements must take into account that in women the thoracic, and in men the abdominal, style of breathing should exert some influence, and must explain why greater and lesser relative movements of the upper parts of the thorax both produce the same results upon the upper lobes.

Once more reverting to the theory that coughing empties more thoroughly the lower than the upper lobes, and even drives air and secretions into them, and that this is caused by relatively slight apex motion, let me call attention to the fact that the statement usually made, that the upper thorax evidently does not move in coughing as much as the lower, and evidently bulges during the forcible expiration of cough, is not altogether true. The upper part of the thorax only *seems* to bulge out in this case, because during the forced inspiration preceding the cough the lower ribs are fixed by the diaphragm, while the upper ones move more freely. The upper thorax is thus bulged out. When the cough expiration occurs, the lower ribs move less than the upper, and also are *sooner* fixed by the abdominal muscles. Hence the upper chest during expiration has been thought to be actually expanded when it is only so relatively to the lower. There is no such thing as forcing air into the upper lobes in coughing expiratory movement.

To the question "How does the tubercle virus find its way into the blood?" it seems correct to reply that the path of the virus is probably through the lymph channels, being absorbed by lymphatics in the mouth, nose, trachea, larger bronchi, gastro-intestinal tract, or in any way the bacilli, with, perhaps, some cheesy matter and white cells, enter through the thoracic ducts into the venous blood. These masses of bacteria, etc., are lodged in the upper lobes. If very small, they are apt to be found at the pleural surface; if large, they are lodged in some branch of the pulmonary artery of the upper lobe, a little nearer the root of the lung.

Of course this is all conjecture, yet experiments now under progress make it seem very probable. I hope in the future to demonstrate by various devices that the theory is almost certainly correct.

It is well, I think, before closing, to outline the methods of study by which I hope to learn something about the path followed by the tubercle bacillus in entering the lungs. Of course microscopic studies of tuberculosis as found in the lungs in the lower animals induced by injection into the veins or the aqueous chamber, the peritonæum, or elsewhere, and of acute miliary tuberculosis in the human lung, must form a large part of the work. It is rather interesting to inquire whether those tubercles which are found in the lungs after intravenous or other extra-pulmonary injections can be shown to differ in their relations to the air vesicles from the tubercles found in cases where inhalation has been supposed to lead to the infection. Tuberculosis of the lungs following artificial inoculation may occur in more or less widely separated nodules, or may present rather localized masses. These masses may distinctly show a tendency to affect the apices or they may not. It is necessary to practice intravenous injections with bacilli contained in media of varying consistence and specific gravity.

So far as inhalation experiments go, a most important thing is, evidently, to exclude all possible effect of the blood current. A living animal eats, breathes through passages presenting a large surface of mucous membrane, and is possessed of lymphatics, and it is quite possible that substances supposed to have entered the lungs by inhalation have really been introduced by the lymph or blood or both. In order to eliminate this source of error, the device of preserving lungs in an elastic condition is worthy of experiment, and I hope will be of value. It is possible thus to prepare lungs, and it is also possible to cause an artificial circulation if a fluid like a thin oil which does not exude from the vessels is employed. The method by which these elastic lungs are made is based upon the use of the old glycerin-carbolic-acid mixture. After injecting the organs with

a solution of chromic acid, alcohol, acetic acid, and water, a solution of glycerin and carbolic acid is made in water. This is injected, and after it has been as far as possible drained out of the lungs, the process is completed by injecting some fixed oil like olive oil, containing a small amount of some essential oil. The lung thus prepared retains an elasticity which seems to be as nearly as possible the same as that of one freshly removed. I show a specimen taken from the body at an autopsy January 11, 1890.*

It will be seen that in this specimen the color is nearly natural, that the surface of the lung when collapsed is rather wrinkled, which is not natural, but that the organ expands and contracts in a manner which makes it hard to believe that it was not just removed from the body. On percussion, we get a normal note when the lung is inflated. Auscultation while air is alternately introduced and expelled shows what seems to be an exaggerated but otherwise a normal vesicular murmur. With such lungs I hope to ascertain where fine powders lodge. Of course it is necessary to arrange the apparatus so that the lung inspires and is not expanded by compressed air. A negative pressure on the lung surface from chest expansion draws air in. It is preposterous to compare the effects of positive pressure at the trachea with the effects of negative pressure at the lung surface. The currents resulting from the rush of air toward a partial vacuum are very different from those caused by air propelled by pressure exerted behind. Pushing and pulling an elastic substance produce very different results, and the elastic air must behave quite differently when it is drawn in toward a lessened resistance than when forced by pressure behind toward a greater. Evidently, during inspiration the first effect of chest expansion is to

* This was shown at the last meeting of the Pathological Society and the details of the method of preparation were given.

rarefy the air in the lobules. This rarefaction progresses rapidly through the bronchi and trachea, and results in a rush of air through this latter. It will be noted that under these circumstances the resistance is progressively less as we go from the center toward the periphery. In the case of air forced in by positive pressure the resistance is always greater near the surface than at the center. Expiration always occurs under positive pressure, however the lung is inflated. I must ask your pardon for going into this sort of detail, but it seems that the simplest lung physics are not well understood by many physicians, and this particular question of positive and negative pressure and their effects upon elastic and non-elastic media seems especially troublesome. Physicists seem to have overlooked the behavior of fluid media like the blood in elastic tubes like the blood-vessels, and I have been unable to find information of a positive kind about the behavior of elastic media like air in elastic tubes like the bronchi and pulmonary lobules. The problems are very complicated, but this much may, I think, safely be asserted: that there can be no doubt that in every case the speed of the air currents in the lungs is in proportion to the resistance ahead, and therefore is relatively greater in the smaller bronchi and air-passages than in the larger when sucked in as in normal inspiration, and greater in the larger than the smaller when forced in by positive pressure.

Under the negative pressure caused by inspiration the air first moved is that in the lobules, and that last moved in the upper respiratory passages. Under positive pressure this is reversed; the air in the upper passages is first compressed, and that in the lobules last. The most rapid and earliest motion is near the center under positive, and near the periphery under negative pressure. When inspiration begins, let us suppose that the air in the lungs is everywhere at rest.

(This is not the case, in fact, for there is still some little air passing out of the trachea, as can be seen, until a little expansion of the thorax has begun.) The result of the chest expansion is, as has been said, to cause a rush of air into the lungs. This rush begins in the peripheral parts. At the end of the inspiratory expansion the air still continues to rush in, since the great resistance caused by friction, etc., prevents it from immediately following the chest movements and filling the partial vacuum. The chest now begins to collapse in expiration. The result is that the air in the peripheral parts first, as the negative pressure is arrested, stops, and then under the positive force caused by the collapsing thorax first momentarily becomes motionless, and then, the expiratory pressure being greater than that of the atmosphere, begins to rush out through the smaller bronchi, and first brings the air rushing in through these tubes to a standstill and then causes it to be expelled. In connection with this it is interesting to note that there is normally no very appreciable interval between inspiration and expiration in healthy chests in which the vesicular murmur is audible, but that when bronchial breathing is heard through hepatized lung or under any circumstances, there is a distinct pause between the inspiratory and expiratory sounds. Theoretically the air in the lobules should very quickly be affected by respiratory movements, while in the larger tubes a much longer interval ought to elapse before the rapid inrush of air during inspiration is stopped, and then theoretically some little time should elapse before the pressure in the lobules could travel through the smaller to the larger tubes and cause the outward rush. Those who believe that the vesicular murmur is only a modification of the bronchial note should think this over and explain it.

I hope at some future date to demonstrate, by studies of elastic lungs under negative inspiratory and positive expi-

ratory pressure, certain matters of interest in respect to the mode of infection by the tubercle bacillus, and also perhaps to some questions of physical diagnosis.

I attempt in this paper to give an idea of the results of two years' work. Of course, it is impossible to give any adequate representation of the specimens shown to one who does not see them. To summarize what I think is shown is very easy :

1. Corrosion preparations are valuable in the study of the lungs.

2. In the lungs these preparations show that the course of the arteries and bronchi is practically the same. They run in a direction normal to the planes of expansion. The veins run far from them and frequently cross them, and their course is such as to make it probable that the blood-pressure within them is little affected by respiratory movements.

3. It is not proved that the air currents in the lung during inspiration and expiration are able to cause the bacillus of tuberculosis to lodge so often in the upper lobes and near the pleural surfaces.

4. Those who maintain that the motion of the chest walls causes in any way such movements of the lungs as to inspire tubercle bacilli into the upper lobes so frequently must explain two things: (a) Why the greater relative movement of the upper part of the thorax in women and the smaller relative movement of the same region in men *alike produce this effect*, and (b) why pneumococci usually lodge in the lower lobes if they also are inspired?

5. The course of the pulmonary arteries and the laws of bodies in fluid media in motion in curved tubes make it *certainly worth while to ascertain whether these blood-vessels do not carry the bacteria to their usual seat.*

This is all. Let me remind any one who asks, What is

the use of all this? of the reply of Faraday to the simple-minded idiot who inquired, in regard to the first electrical machine, "What is the use of it?" The retort contemptuous was: "What is the use of a baby?" Of course, had the sarcastic scientist been a member of our own profession, he would have appreciated the most immediate use of a baby, financially at least. It is always worth while to try to learn a little more about anything. I had no idea, however, that this same work might possibly prove of "practical" value. If lung surgery is to be, through Koch's work, a matter of immediate importance, as is possible, then perhaps this infant of mine may prove useful to the surgeon.

If the study is of no surgical value, a reply to one asking this most irritating question, as to the tangible and immediate use of *any* work which is less contemptuous than that of Faraday, may be really more just, and is certainly more courteous. It is this: If it has no other use, it may show some one that it is needless to waste time in undertaking similar studies. Time is the one invaluable thing in the world, for, if wasted, it never can be replaced. A blunder is worth something if it is recorded, so that some other man may avoid a similar one. It is worth while to do something, even if only to prove that it is not worth doing again. Besides all this, facts are always of value, often of unexpected value. If this work has added even a little to any one's knowledge, it is of use.



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